CALCULATING MREM PER CI FACTORS

Purpose

This Meteorology and Air Quality Group (MAQ) procedure describes how mrem per Curie factors are calculated for LANL sources of radioactive air effluents.

Scope

This procedure applies to the individuals assigned to calculate mrem per Ci factors for the Rad-NESHAP Project and New Source Review Project.

In this procedure

This procedure addresses the following major topics:

Signatures

Prepared by: Keith W. Jacobson Keith W Jacobson, MAQ	Date: 03/06/06
Approved by: David Fuehne Digitally signed by David Fuehne DN: cn=David Fuehne, c=US, o=Rad-NESHAP Team, ou=ENV-MAQ, email=davef@lanl.gov Reason: I am approving this document Date: 2006.03.23 12:39:15 -07'00' Dave Fuehne, Rad-NESHAP Project Leader	Date: 03/06/06
Approved by: Signature on File - tlm Terry Morgan, QA Officer	Date: 03/13/06
Work authorized by: Dianne Wilburn Dianne Wilburn, MAQ Acting Group Leader	Date: 03/13/06

03/13/06

General information about this procedure

Attachments

This procedure has the following attachments:

Number	Attachment Title	No. of pages
1	CAP88 source Term Validation and Decay Chain Analysis Form	1
2	Example ‘u-‘ Script and other Unix Scripts used	5

History of revision

This table lists the revision history and effective dates of this procedure.

Revision	Date	Description Of Changes
0	6/14/00	New document.
1	11/01/01	Split out part of procedure to MAQ-512 and updated process.
2	3/16/06	Quick-change revision to reflect running CAP88 on a new server, and add two new definitions.

Who requires training to this procedure?

The following personnel require training before implementing this procedure:

- Health physicist assigned to calculate mrem/Ci factors

Training method

The training method for this procedure is **mentored training** and is documented in accordance with the procedure for training (MAQ-024).

Prerequisites

In addition to training to this procedure, the following training is also required prior to performing this procedure:

- Experience or education in the field of health physics
- MAQ-501, “Dose Assessment Using CAP88”

General information, continued

Definitions specific to this procedure

'u-' script: A Unix-shell script used to control the running of CAP88 and other Unix programs and datafiles that generates a final list of mrem per Ci factors for a release point.

Mrem/Ci: the potential radiological dose to a public receptor per Ci of a given radionuclide released from a point source.

EDE: (effective dose equivalent) the type of dose calculated by CAP88.

NCRP: acronym for National Council on Radiation Protection.

References

The following documents are referenced in this procedure:

- MAQ-024, "Personnel Training"
- MAQ-501, "Dose Assessment Using CAP88"
- DOE Memo for Record: LAAME:6SF-023, Aug 18, 1998
- ESH-17:99-506, Letter to Mr. Steve Fong, Nov 24, 1999
- EPA 520/1-89-001 "Background Information Document - Procedures Approved for Demonstrating Compliance with 40 CFR 61, Subpart I" October 1989
- DOE letter, U.S. DOE Office of the Environment, from Mr. Stephen C. Fong to U.S. EPA Radiation Program Manager, Mr. George P. Brozowski, RE: Addition of Three Radionuclides to CAP88, Aug 18, 1998
- Grove Engineering Inc., **RadDecay** software program, Rockville Maryland, 1995
- Richard B. Firestone, "Table of Isotopes" Eighth Edition, CD-ROM, John Wiley and Sons, Inc., 1996
- National Council on Radiation Protection and Measurements Report No. 123, "Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground", 1996

Note

Actions specified within this procedure, unless preceded with "should" or "may," are to be considered mandatory guidance (i.e., "shall").

Calculating mrem per Ci factors

Background

The purpose of calculating mrem/Ci factors is to allow any member of MAQ to perform a dose assessment for an existing, new, or proposed facility (or new operation) without having to run a dose model. The user multiplies the expected emissions (in Ci) times the listed dose factors to obtain the environmental impact.

EPA approval

At this time, the Meteorology and Air Quality group does not require and is not seeking EPA approval for this procedure.

Assumptions and methodology

For most radionuclides, the mrem per Ci factor is simply the dose calculated by CAP88 for a unit release of the radionuclide. However, many radionuclides decay to other radionuclides which may or may not contribute to dose, depending on the half-life of the parent and progeny, the branching ratios, and the dose factors of the progeny.

For most cases, NCRP #123 was used as a guide to determine which progeny to include in the source term for a mrem/Ci calculation. Following the NCRP report, the in-growth time was assumed to be 30 years, with a few exceptions. In other cases, the precedent set by the original distribution of the CAP88 package was followed. A form and peer review process was developed for documenting the steps used to determine if a radionuclide's progeny were included in a mrem per Ci calculation, as discussed in the next chapter.

Calculate mrem per Ci factors

There are three basic parts to calculating mrem/Ci factors for a facility: obtaining release point information, evaluating receptor locations, and running the controlling scripts. The controlling scripts write a text file that is uploaded to a database of release points.

The calculations are currently performed on *wxmach* with the main-frame version of CAP88. The Meteorology and Air Quality group has devised a number of small programs and data libraries which are used to automatically calculate dose factors for about 300 radionuclides for a given release point. These are all controlled by the 'u-' script, a Unix-shell file that will cycle through about 25 pre-canned source term files. These trailer files should be located in the current working directory on *wxmach*. The header of the source term files also resides on *wxmach*. An example script is provided as attachment 2. Follow the steps below to calculate factors for a release point. The user should have an account on *wxmach* with access to the CAP88 programs and applicable scripts.

Calculating mrem per Ci factors, continued

Steps to generate mrem per Ci factors for an individual release point

To generate mrem per Ci factors for an individual release point, perform the following steps:

Step	Action
1	Obtain information regarding the release point, specifically the physical height of the stack, diameter, and exit velocity. If this information is unknown, use the default stack height value of 10m, as suggested in the CAP88 users' manual.
2	Obtain the X and Y location of the stack. This can be done via the ArcView system maintained by the EES-5 group or through other GIS resources available at LANL. Maps should be generated that show the nearest public receptor locations to the release point.
3	Obtain a multi-year average of meteorological data using the LANL met-tower nearest to the source (see MAQ-501 for guidance). This can be downloaded from the following web-site: http://weather.lanl.gov/. Log onto *wxmach*, use the FTP utility to upload the file from your PC, and ensure the file is in the current working directory on *wxmach*.
4	A generic file of population has been constructed for the mrem/Ci process. It must be in the current working directory on *wxmach*. The file has receptors in all sectors and the population density matches that of Los Alamos county.
5	It will be necessary to identify the highest EDE receptor location (since it is not always the nearest receptor). The user should perform some preliminary CAP88 runs to perform this analysis. Document the identification of the highest EDE location in the records.
6	Determine the X and Y value of the receptor location identified in step 5. Using this data, the distance and direction can be calculated using ordinary trigonometry based on the release point X and Y value obtained in step 2. Verify that this has been done.

Steps continued on next page.

Calculating mrem per Ci factors, continued

Step	Action
7	Change into the directory on *wxmach* containing the header files for the release points. Create or edit the necessary file for the release point in question. Ensure the release point ESH-ID number is given on or about line 16 of the file. Verify the correct stack parameters are given on or about line 27 of the file. An example header file is given below. 1 Keith Jacobson 2 (505) 665-6080 3 pre03006601 4 9299ta06.cap 5 pop98d 6 pred_nuc 7 * 8 Los Alamos National Laboratory 9 ESH17 ms:j978 10 Los Alamos 11 nm 12 87545 13 usage 14 * 15 Calculate the mrem/Ci factor from TA-3-66-1-FE-7,8 emissions. 16 03006601=esid#, receptor: 644 N, i=01, j=06, default dia, vel. 17 option 18 $opti option=0,1,0,1,0,0,0,1,1,lipo=1,nstb=2,tsubb=15. $end 19 grid 20 $grid nol=1,nou=16,nrl=1,nru=20, 21 22 lat=35.8667, lon=106.25, $end 23 meteorological data 24 $mete lidai=1525,rr=45.3,ta=282.,tg=0.02,0.035,0.035,z=10. $end 25 physical source data 26 1 27 $phys ph=19.1 $end 28 wind frequency data 29 radionuclide data In this case the ESH-ID is 03006601. This number is read by the 'u-' script to identify the particular release point for the mrem per Ci calculations.

Steps continued on next page.

Calculating mrem per Ci factors, continued

Step	Action
8	Verify that the necessary files and programs are present in the working directory for non-CAP88 radionuclides. This includes the table of dose-factors discussed in section 1 of this report. This file should be called 'confac'. These factors are used by the program 'calcon.awk' to calculate doses from concentrations extracted from the CAP88 runs. The concentrations are extracted by the 'getcon.sh' script. Generate the 'calcon.awk' program by running 'facfmt.awk' and ensuring the 'confac' file is present.

9	Create or edit the 'u-' script file used to perform the CAP88 runs. The 'u-' script will run through a series of about 25 source term files for each release point. An example 'u-' script is given as attachment 6. An example source term file for Pa-231is given below.
	`4`
	`$radi nuc="pa-231", rel=1.00e+00 $end`
	`$radi nuc="ac-227", rel=1.00e+00,i1=-1,f=4.824e-01 $end`
	`$radi nuc="th-227", rel=1.00e+00,i1=-2,f=9.894e+01,2.056e+02 $end`
	`$radi nuc="ra-223", rel=1.00e+00,i1=-3,`
	`f=1.615e+02,3.360e+02,1.635e+00 $end`
	
	`population array`
	`comments`
	`Pa-231 decay chain modeling.`
	`31-Aug-2001=last modified KwJ.`
	`modifications`
	`3`
	`$modi nuc="ac-227", anlam=0.00 $end`
	`$modi nuc="th-227", anlam=0.00 $end`
	`$modi nuc="ra-223", anlam=0.00 $end`
	
	Run the 'u-' script by typing its name at the screen prompt.

10	When the 'u-' script is completed, the final list of mrem/Ci factors are printed to the screen. The file is to be electronically uploaded into a database.
11	Print out an official copy of one of the CAP88 output files to be included in the peer review process, as discussed in MAQ-501.
12	Using the CAP88 output file, verify the electronic upload of the mrem per Ci factors to the database.

Decay chain analysis

Background

Many of the radionuclides encountered at LANL belong to a decay chain in which there may be contributions to the overall dose from progeny in the chain. In order to ensure that doses are not underestimated, in certain cases dose factors from progeny are summed to the dose factor of the parent. Progeny can exist in secular equilibrium, transient equilibrium, and non-equilibrium. The Meteorology and Air Quality group used NCRP report #123 as a guide to determine which progeny are to be included. If a deviation from the NCRP report is made, it is thoroughly documented and peer reviewed.

EPA approval

The Meteorology and Air Quality group does not need nor is it seeking EPA approval for this analysis. EPA has established the precedent of performing decay chain analysis by distributing decay chain files for U-238 (natural) and Th-232 (natural) and the Fortran program "Chain.for" as part of the original CAP88 code package. Thus, the user should apply the analysis in other cases, consistent with the EPA-approved model CAP88.

Develop decay chains

The first step is to obtain a current list of the radionuclides used for developing mrem per Ci factors at LANL. This consists of about 150 radionuclides in CAP88 and about 150 non-CAP88 radionuclides (see MAQ-512). Once a list has been obtained, perform the following steps.

Steps to develop decay chains

To develop decay chains, and the associated CAP88 source term or input file, perform the following steps:

Step	Action
1	For each radionuclide in the list, determine if there are radioactive progeny. The use of programs such as RADDECAY© can be very useful for this step. If a radionuclide is not in RADDECAY, other references such as "The Table of Isotopes" can be used.
2	Follow the information requests on CAP88 source Term Validation and Decay Chain Analysis Form (Attachment 1). The form asks the user to check NCRP report #123 to see if there is significant contribution to dose by the progeny.

Steps continued on next page.

Decay chain analysis, continued

Step	Action

3	If the user has determined that progeny are to be included in the source term calculation, the next step is to run the 'chain.for' program to obtain the necessary CAP88 adjustment factors. An example-input file is given below.
	
	`cs-137 ==> barium 137m ingrowth`
	`    2            30. Years`
	`  cs-137    3.00e+01 y             0.946  5.48e-05 d`
	` ba-137m      2.5520 m                    5.48e-05 d`
	
	After the input file has been edited with the half-life and branching ratio to the progeny, run the 'chain.for' program. An example output file is given below.
	
	`input data:`
	` title:              cs-137 ==> barium 137m ingrowth`
	` n,t,tunit:              2          30.00 years`
	` name,h,hunit,f,e eunit:`
	`                       cs-137   3.000E+01 y          0.94600 5.480E-05d`
	`                      ba-137m   2.552E+00 m          0.00000 5.480E-05d`
	` Calculated values for q, r and s (y**-1).`
	
	`cs-137        2.305E-02   2.002E-02   1.429E+05`
	`ba-137m       1.429E+05   2.002E-02    .000E+00`
	` cs-137 --> barium 137m ingrowth`
	` airdos-epa ingrowth factors calculated for`
	` time=     30.00 years`
	
	` nuclide      ingrowth factor for parent nuclide`
	
	`               cs-137`
	`  ba-137m   3.406E+06`
	
	In this example, the value of 3.406E+06 would be included on the input line of the Ba-137m source term to ensure that ground surface activity of Ba-137m is tied to the activity of Cs-137. This step should be repeated for other decay chains identified. The input lines in the source term file containing the Cs-137/Ba-137 decay chain should look like the following example.
	
	`  $radi nuc="cs-137", rel=1.00e+00 $end`
	`  $radi nuc="ba-137m",rel=1.00e+00,i1=-1,f1=3.406e+06 $end`
	
	Ensure the source term has been modified to include the buildup factors for radionuclide decay chains identified in step 2.

Records resulting from this procedure

Records

The following records generated as a result of this procedure are to be submitted **within 2 weeks** as records to the records coordinator:

- copy of highest EDE receptor analysis
- CAP88 output file(s)
- CAP88 Source Term Validation And Decay Chain Analysis Form (Attachment 1) (when applicable)

Meteorology and Air Quality

CAP88 SOURCE TERM VALIDATION AND DECAY CHAIN ANALYSIS FORM

This form is from MAQ-511

CAP88 file name of source term:

	Yes	No	N/A
Are these radionuclides included in the CAP88 dose factor libraries?			
Attach tables, charts or diagrams for radionuclides in input file that belong to a decay chain, showing parent and progeny.			
Are progeny are listed in NCRP #123?			
If not listed in NCRP#123, is sufficient justification provided for modeling progeny or other isotopes?			
Attach sufficient data with references providing half-life, branching ratios, activity fraction, and other information needed for the evaluation.			
Attach copy of output from 'chain.for' program and verify correct data used.			
Attach copy of CAP88 input file and verify that correct data were used.			
Attach copy of CAP88 output to demonstrate calculations performed as expected.			
If CAP88 input file is replacing a previously used source term, attach comparison of output from previous method.			

I certify that the data, calculations, final result, and documentation are complete for this radionuclide.

_____ _____ _____
Preparer's signature Name (print) Date

I have peer-reviewed the data, calculations, final result, and documentation, including the items listed above.

_____ _____ _____
Reviewer signature Name (print) Date

EXAMPLE 'U-' SCRIPT AND OTHER UNIX SCRIPTS USED

u55-4-16.sh

```
--------------------------------------------------------------------------------
#!/bin/ksh
#
# KSH script file for mrem per Ci dose factor runs with CAP88.
# 22-Mar-2000 == last modified by KwJ
# Edit parameters in 'edit module' for different stacks; i.e.
# always edit lines 20, 24, and 28; also,
# edit 32 if different met-tower used.
#
test -f prepnpt && rm prepnpt
test -f predain && rm predain
test -f popdat  && rm popdat
test -f metdat  && rm metdat
#
#
### begin of edit module ###
cp ~/cap88/use/pop98d pop98d
sed 's/ 0.95, 1.05,/1.052,1.152,/' pop98d > popdat
#
cp ~/cap88/use/preda_nuc pred-tmp
sed 's/iloc=00,jloc=00/iloc=16,jloc=10/' pred-tmp > predain
#
cp ~/cap88/use/ta55/pre55000416 pre-tmpl
#
cp ~/cap88/use/9299ta06.cap metdat.cap
sed '10d' < metdat.cap | sed '1,6d' | sed 's/starn1/starnl/' > metdat
### end of edit module ###
#
cat pre-tmpl single > prepnpt
cp prepnpt prepnpt.single
eval runit
eval getnuc16.x
cp ftn55 rad.txt
#
cat pre-tmpl singl2 > prepnpt
eval runit
eval getnuc16.x
cat ftn55 >> rad.txt
#
cat pre-tmpl short > prepnpt
eval runit
eval getnuc16.x
cat ftn55 >> rad.txt
#
cat pre-tmpl prs > prepnpt
runit
 eval getnuc16.x
 eval sumprs.x
cat ftn66 >> rad.txt
#
cat pre-tmpl prs2 > prepnpt
runit
 eval getnuc16.x
 eval sumprs.x
cat ftn66 >> rad.txt
#
#
cat pre-tmpl i135 > prepnpt
runit
```

```
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl pa231 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl pb210 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl pu236 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl pu244 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl ra223 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl ra224 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl ra226 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl ra228 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl sr91 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl u232 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl u238 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl u-nat > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 | sed 's/u-238/u-nat/' >> rad.txt
#
cat pre-tmpl u-dep > prepnpt
runit
```

```
eval getnuc16.x
awk -f radisum.awk ftn55 | sed 's/u-238/u-dep/' >> rad.txt
#
cat pre-tmpl u-enr > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 | sed 's/u-235/u-enr/' >> rad.txt
#
cat pre-tmpl th228 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl th229 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl th230 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl th232 > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 >> rad.txt
#
cat pre-tmpl th-nat > prepnpt
runit
eval getnuc16.x
awk -f radisum.awk ftn55 | sed 's/th-232/th-nat/' >> rad.txt
#
##### revised stuff begins below ######################################
cat pre-tmpl singl3 > prepnpt
eval runit
eval getnuc16.x
cat ftn55 >> rad.txt
#
#
cat pre-tmpl prscon1 > pre-prscon1
sed 's/=0,1,0,1,0,0,0,1,1/=0,1,0,1,0,0,0,0,1/' pre-prscon1 > prepnpt
runit
getcon.sh
awk -f calcon.awk con1.txt > pcon1.txt
cp pcon1.txt ftn55
eval sumprs.x
cat rad.txt ftn66 | sort -u > rad1.txt
#
#
#
#
cat pre-tmpl prscon2 > pre-prscon2
sed 's/=0,1,0,1,0,0,0,1,1/=0,1,0,1,0,0,0,0,1/' pre-prscon2 > prepnpt
runit
getcon.sh
awk -f calcon.awk con1.txt > pcon2.txt
cp pcon2.txt ftn55
eval sumprs2.x
cat rad1.txt ftn66 | sort -u > rad2.txt
#
#
#
cat pre-tmpl con > pre-con
sed 's/=0,1,0,1,0,0,0,1,1/=0,1,0,1,0,0,0,0,1/' pre-con > prepnpt
```

```
cp prepnpt pre-con
runit
getcon.sh
awk -f calcon.awk con1.txt > cal1.txt
cat rad2.txt cal1.txt | sort -u > rad3.txt
#
#
cat pre-tmpl con2 > pre-con2
sed 's/=0,1,0,1,0,0,0,1,1/=0,1,0,1,0,0,0,0,1/' pre-con2 > prepnpt
cp prepnpt pre-con2
runit
getcon.sh
awk -f calcon.awk con1.txt > cal2.txt
cat rad3.txt cal2.txt | sort -u > rad4.txt
#
#
cat pre-tmpl con3 > pre-con3
sed 's/=0,1,0,1,0,0,0,1,1/=0,1,0,1,0,0,0,0,1/' pre-con3 > prepnpt
cp prepnpt pre-con3
runit
getcon.sh
awk -f calcon.awk con1.txt > cal3.txt
cat rad4.txt cal3.txt | sort -u > rad5.txt
#
#
cat pre-tmpl con4 > pre-con4
sed 's/=0,1,0,1,0,0,0,1,1/=0,1,0,1,0,0,0,0,1/' pre-con4 > prepnpt
cp prepnpt pre-con4
runit
getcon.sh
awk -f calcon.awk con1.txt > cal4.txt
cat rad5.txt cal4.txt | sort -u > dfacs.out
#
rm rad.txt rad1.txt rad2.txt rad3.txt rad4.txt rad5.txt
rm cal1.txt cal2.txt cal3.txt cal4.txt
rm pcon1.txt pcon2.txt
rm ftn55 ftn66
rm con1.txt
cat dfacs.out
#
echo "****end of Script, use caprun.sh to generate review files****"
wxmach-kwj>
```

getcon.sh

```
--------------------------------------------------------------------------------
#!/bin/csh
# CSH script to parse concentrations from cap88 output file based on #
# distance and direction used for the individual assessment, writes  #
# con1.txt that will be used by CALCON.awk to generate factors       #
# 02-Apr-1999 == last update by KwJ
set dis=`grep "===>" cap88out | awk '{print$2}'`
set dir=`grep "===>" cap88out | awk '{print$4}'`
set esid=`grep 'esid#' cap88out | cut -c2-9`
echo 'The distance is' $dis', and the direction is' $dir 'for' $esid
grep $dis cap88out | \
awk '{printf("%-3s %6d %-8s %-8s %9s\n",$1,$2,$3,$4,"xxx")}' \
  | sed "s/xxx/$esid/" | grep ^$dir' ' > con1.txt
echo '*** end of getcon script ***'
--------------------------------------------------------------------------------
```

factmt.awk

```
--------------------------------------------------------------------------------
#FACFMT.awk formats the flat non-cap88 dose factors file (CONFAC)  #
# for input to the CALCON.awk pgrm as an array.  #
# 02-Apr-1999 == last update by KwJ  #
BEGIN { x = 1
 print "BEGIN {" }
{
print "  list["x"] = \""$1"\" ; val["x"] = "$2
x++
}
END { print " canned = "  NR  " }" }
--------------------------------------------------------------------------------
```

calcon.pgm

```
--------------------------------------------------------------------------------
#CALCON.awk calculates mrem/Ci factors from cap88 output concentrations#
# run FACFMT.awk with CONFAC as input to generate lookup array which is#
# appended as a header to this pgrm, 02-Apr-1999==last updated by KwJ  #
{
 a_name[NR] = $3
 a_con[NR] = $4
}
END {
 {for (x = 1; x <= canned; x++) # loop for each radionuclide in list
   for ( y = 1 ; y <= NR; y++ ) # loop for each concentration read in
    if ( a_name[y] == list[x]) dose[y] = (a_con[y] / val[x]) * 1.0e-11 }
# print-out loop, $5 is esid number from input file
 for (z=1; z <=NR; z++)
  printf("%-8s   %-7s     %-8.2e\n", $5, a_name[z], dose[z])
}
--------------------------------------------------------------------------------
```

radisum.awk

```
--------------------------------------------------------------------------------
#RADISUM.awk sums progeny factors to parent in decay chain  #
#BEGIN { print "* summing progeny factors to parent in chain *" }
{ if (NR<2) esid = $1 }
{ if (NR<2) radi = $2 }
{ total = total + $3 }
END { printf("%8d   %-7s %12.2e\n", esid, radi, total)}
wxmach-kwj>
```

Meteorology and Air Quality

CAP88 SOURCE TERM VALIDATION AND DECAY CHAIN ANALYSIS FORM

This form is from MAQ-511

CAP88 file name of source term:

	Yes	No	N/A
Are these radionuclides included in the CAP88 dose factor libraries?			
Attach tables, charts or diagrams for radionuclides in input file that belong to a decay chain, showing parent and progeny.			
Are progeny are listed in NCRP #123?			
If not listed in NCRP#123, is sufficient justification provided for modeling progeny or other isotopes?			
Attach sufficient data with references providing half-life, branching ratios, activity fraction, and other information needed for the evaluation.			
Attach copy of output from 'chain.for' program and verify correct data used.			
Attach copy of CAP88 input file and verify that correct data were used.			
Attach copy of CAP88 output to demonstrate calculations performed as expected.			
If CAP88 input file is replacing a previously used source term, attach comparison of output from previous method.			

I certify that the data, calculations, final result, and documentation are complete for this radionuclide.

_____ _____ _____

Preparer's signature | Name (print) | Date

I have peer-reviewed the data, calculations, final result, and documentation, including the items listed above.

_____ _____ _____

Reviewer signature | Name (print) | Date